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# A Fuzzy Local Path Planning and Obstacle Avoidance for Mobile Robots

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## Abstract

This paper presents a local fuzzy path planning and obstacle avoidance method based on fuzzy logic. The main idea is to fuzzify the obstacles in the environment and use a fuzzy logic controller to guide the robot not to move too close to the obstacles. The human sense of obstacles and his behavior in obstacle avoidance is provided the *Fuzzy Obstacle* concept which is used in the obstacle avoidance unit.

The advantage of local path planning approaches is their short response time and ability to be used in real-time implementations. But these methods suffer from local minima. This method has decreased the probability of having a local minimum compared to Khatib's potential field method. The new method is easily applicable in non-holonomic mobile robots.

**Keywords:** Mobile Robot, Obstacle Avoidance, Fuzzy Logic Controller, Local Path Planning, Artificial Potential Field

## 1 Introduction

Despite the impressive advances in the field of autonomous robotics in recent years, a number of problems remain. Most of the difficulties originate in the nature of real-world, unstructured environments, and in the large uncertainties that are inherent to these environments. Also, the effect of control actions is not completely reliable [3]. So there is no need to apply the sensory data exactly in our computations. Using this data as a fuzzy data in path planning methods, should be a good idea.

Path planning is a well-known and an important problem in the field of robotics. The objective in this problem is to find a collision free path between a start and a goal configuration in an environment containing stationary or moving obstacles. In recent years, there has been a great effort on motion planning of mobile robots. And two major methods in this field have arisen; Global Path Planning approaches and Local Path Planning approaches. Each method has its own advantages.

In global path planning approaches, the optimal path can be obtained. But these methods suffer from extensive computation and the requirement of a priori knowledge about the environment. These methods can be used in industrial robots which do not need to have flexibility or autonomy. So these robots are not able to operate in new environments or to face unexpected situations.

The advantage of local path planning to the global path planning approaches is their short response time and their real-time implementations and ability to be used in unknown environments. But they suffer from local minima, limit cycles, and instability problems [4].

The environments of real robots are rarely predictable or perfectly know. So it does not make sense to make precise plans before moving [3]. In this paper, we have provided a new fuzzy path planning and obstacle avoidance method by which the probability of going to a local minimum trap is decreased compared to Khatib's artificial potential field method. The new method is easily applicable in non-holonomic mobile robots.

The paper is organized as follows: In section 2, the concept of fuzzy obstacle avoidance is illustrated. Section 3, describes the algorithm proposed for the object avoidance unit, and shows the fuzzy logic controller for it. A brief description of the goal seeking method in the proposed algorithm is in Section 4. The simulation results are presented in Section 5 followed by the conclusions in Section 6.

**Note:** In this text, we have added the dimension of the robot to the obstacles. Hence the robot is considered as a point. See the concept of C-Obstacles and C-Surface in [1].

## 2 Fuzzy Obstacle Avoidance

In developing the new strategy, the Khatib's obstacle avoidance method which is based on an *artificial potential field,* is influenced. Khatib computes an artificial potential field that has a strong repelling force in the vicinity of obstacles and an attracting force produced by the target location. The superposition of the two forces created a potential field, which incorporates information about the environment. Following the steepest gradient from a start position, a path can be found that guides the robot to the target position avoiding obstacles [5].

Consider a human walking in a crowded place. He tries not to collide with people around himself. He pays more attention to the people and objects in front of himself compared to the ones behind him. And as he goes away from an object or a person, he pays less attention to it because the probability of collision with the object decreases.

The human sense of obstacles and his behavior in obstacle avoidance is provided the *Fuzzy Obstacle* concept which is used in the obstacle avoidance unit.

Consider a C-Obstacle that can be expressed as a set of points in configuration space. The fuzzy version of this set can be defined by the following; The membership function of any point in this set is equal to zero if this point is not belong to any C-Obstacle's boundary. The membership equals to one, when the point is exactly front of the robot (or in directions which the robot can move) and it decays as we move away from the robot.

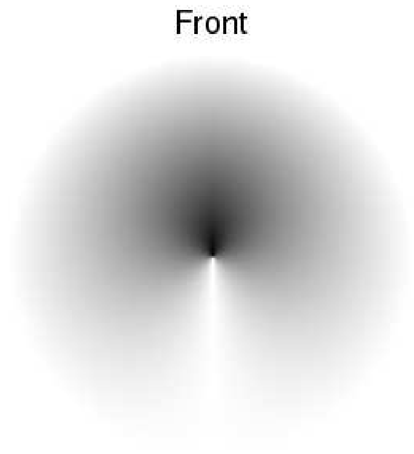



Figure 1 : The *Fuzzy Obstacle* Concept
The figure shows that the fuzziness of the point decreases if the point goes behind the robot or far from the robot

The obstacle avoidance unit is based on a fuzzy logic controller. The task of the fuzzy unit is to provide a control function, which produces an appropriate motor command from the given inputs. The control function can be described as follows: on the one hand the function has to lead the mobile robot to its attraction goal position; on the other hand it has to force the robot to back up when approaching a fuzzy obstacle which conveys a repelling influence. The fuzzy rule-base is built up by using common sense rules.

The inputs to the fuzzy obstacle avoidance unit are the relative angle and distance between the robot and the points on the boundary of the obstacle, and relative distance and angle between the robot and the goal.

The output variable of the unit is the motor command $\tau$. This command can be interpreted as an actuation command for the robot's direction motor, and fed to the mobile platform at each iteration.

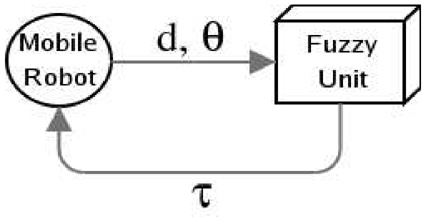
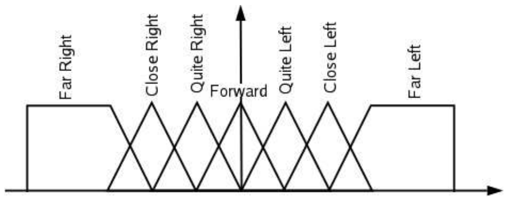


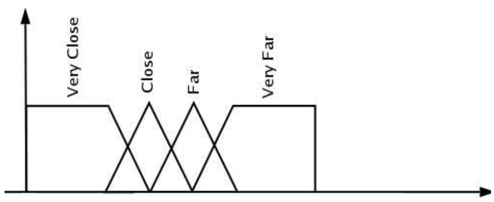

Figure 2: The Fuzzy Obstacle Avoidance Unit

## 3 The Proposed Algorithm

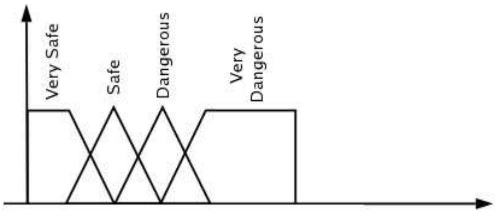
The fuzzy controller in our approach is a two-level fuzzy controller. In the first level, the relative angle and distance data of the point is converted to a fuzzy point, and this fuzzy point is passed to the second level producing the motor command.




(a) Angle from Mobile Robot to the point




(b) Distance from Mobile Robot to the point




(c) Dangerousness of the point

Figure 3 : Fuzzy sets for the Mobile Robot

Each input space is partitioned by fuzzy sets as shown in figures 3-a and 3-b. The asymmetrical triangular and trapezoidal functions are utilized to describe each fuzzy set to allow a fast computation.

Table 1 shows and example for the rules defined in the first level of fuzzy controller. These rules can be written as sentences with two antecedents – relative angle and relative distance – and one conclusion.

The rules for the second level of the obstacle avoidance unit can be written as sentences with two antecedents and one conclusion. The rule base for the second level of the obstacle avoidance unit is shown in Table 2.

| |
|---|
| rule 1: If distance is *very far* and angle is *far left* then point is *very safe.* rule 2: If distance is *very far* and angle is *quite left* then point is *quite safe.* rule 3: If distance is *very far* and angle is *forward* then point is *safe.* rule 4: If distance is *close* and angle is *forward* then point is *dangerous.* *rule 5:* If distance is *very close* and angle is *forward* then point is *very dangerous.* |

Table 1 : A rule base for the first level of obstacle avoidance unit of the Mobile Robot

| |
|---|
| rule 1: If dangerousness is *very safe* and angle is *far left* then command is *very small right.* rule 2: If dangerousness is *very safe* and angle is *close left* then command is *small right.* rule 3: If dangerousness is *dangerous* and angle is *quite right* then command is *big left.* rule 4: If dangerousness is *very dangerous* and angle is *far left* then command is *small right.* rule 5: If dangerousness is *very dangerous* and angle is *forward* then command is *very big right.* |

Table 2 : A rule base for the second level of obstacle avoidance unit of the Mobile Robot

## 4 Goal Seeking Method

To define the goal seeking method for the mobile robot, the human behavior dealing with the goal is considered.

In this method, the goal has a fuzzy value of dangerousness. The goal's dangerousness is low when the mobile robot can see the goal. In other words, when the mobile robot can sense the goal with it's ultra sound sensors (for example), the goal can be reached easily so it has a low dangerousness. The goal would have dangerousness if there is a barring obstacle, so the robot can't find it's path, straight to the goal. The dangerousness of the goal increases when the barring obstacle is close to the goal or the mobile robot.

The relative distance and angle of the obstacles to the goal goes into a fuzzy logic controller to provide a fuzzy value of dangerousness. The second layer of fuzzy controller uses this value to make goal seeking commands to the motors. The dangerousness of the robot determines how much should the robot pay attention to the goal in it's real-time path planning.

This approach in goal seeking helps mobile robot to fall in local minima in less conditions.

## 5 Simulation Results

The behavior of the proposed algorithm is verified with a mobile robot simulation software provided by the author (programmed in C++). The robot moves smoother by the new algorithm compared to artificial potential field approach written before by the author, And does not fall into local minima in many cases. Figure 4 shows a simulation step of the mobile robot.

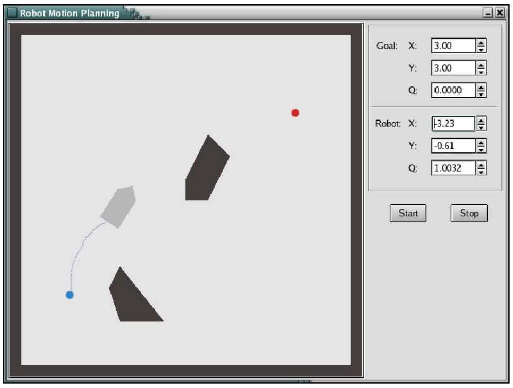



Figure 4 : A simulation step for the Mobile Robot

## 6 Conclusion

This paper proposed a fuzzy based navigator for the obstacle avoidance and navigation problem in mobile robots. The new fuzzy local path planning approach is based on human sense of obstacles and goals. The simulation results show that the robot move smoother compared to the artificial potential field method. Further research needs to be done to improve the algorithm handling the local minima problem.

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